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INCIDENCE OF TUBERCULOSIS IN THE VARIOUS ORGANS OF THE PIGEON

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It is known that tuberculosis of the common fowl is much more frequently found in the liver and spleen than in other organs; that this disease is produced by the avian form of the tubercle bacillus; that other birds and some mammals are susceptible to experimental inoculation with the avian bacillus, and that the pigeon and guinea-pig are probably less easily inoculated than are the fowl and rabbit.

In the course of investigations on sex in doves and pigeons during the past ten years, it has been necessary to make rather careful necropsies on several thousands of these animals. During the last seven years of this period data concerning tuberculosis of each bird were so recorded as to designate the organ which from macroscopic examination seemed most extensively affected; other affected organs were given rank in the order of the extent to which they were invaded by tubercles. In making such a classification there is undoubtedly some opportunity for error and still another factor is introduced by the circumstance that only about six-sevenths of the necropsies were made by the same observer; during one year of the seven-year period all of the necropsies were made by Dr. E. H. Behre. It is thought, nevertheless, that our records afford an approximately consistent and correct description of the facts.

A summary of the classified data thus obtained has recently been made. There is, perhaps, some reason for believing that this summary may be of interest to others than ourselves. Nearly similar data for birds are apparently available only for the common fowl, and in view of a certain amount of knowledge concerning the localization or distribution of phagocytic activity in the organs of the pigeon, the results set forth here may have some bearing on the general subject of tuberculous infection and on the subject of phagocytosis.

Apparently no data are available which show the relative extent to which the various tuberculous organs of any bird were invaded by tubercles. Data for the number of times tuberculous infection was found in each of the organs of the fowl have, however, been supplied by Vosgien¹ and by Raymond and Crétien.² Necropsies made by Vosgien on 145 fowls condemned in a public

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¹ *Hygiene de la Viande*, 1912, 6, p. 207.

² *Ibid.*, 1912, 6, p. 211.

market in Paris showed the following distribution of tuberculosis in the various organs: liver, 143 cases; spleen, 135; lymph glands of neck, 102; lungs, 61; bones and joints, 46; peritoneum, 13; kidneys, 9; ovaries, 6. The organ was considered tuberculous when enlarged and provided with yellowish caseous nodules. Several of these nodules were stained and tested by the method of Ziehl, and it is stated that tubercle bacilli were invariably found.

Raymond and Crétien continued the work of Vosgien and, though they too used fowls condemned later in the same market, obtained somewhat different results. They state that in a tuberculous fowl "the liver and spleen are always infected with tubercle bacilli." It is not clear whether they performed necropsy examinations on 766 or only one-half this number of fowls since they merely give the number of cases of tuberculous "liver and spleen" as 766 cases. Other organs follow in order: lymph glands of neck, 164; bones and joints of hip and shoulder, 79; lungs, 23; gastro-intestinal canal, 17; kidneys, 12; ovary, 3; thyroid, 2. It seems highly probable that Vosgien studied more advanced cases of infection—cases more nearly comparable with our own—and that Raymond and Crétien made use of birds in a much less advanced stage of infection. The report unfortunately leaves this a matter of conjecture. In making tests on the nature of the infections these workers made peritoneal inoculations of rabbits with an emulsion of the caseous exudate of the hip joint of the fowl. Three months later all rabbits are stated to have exhibited tuberculosis of the mammalian type. In these cases "the liver and spleen were much enlarged and bore bacilli but no tubercles." A fowl inoculated in the axillary vein with the exudate from an infected articulation was found emaciated at the end of 2 months and was then killed. The liver and spleen were considerably enlarged and contained many small grayish nodules in which the bacilli were numerous. Other investigators have successfully inoculated fowls, ducks, geese, pigeons, etc., with this bacillus.

These citations have been rather fully considered, not only because they seem to include practically all that has been learned of the relative incidence of tuberculosis in the various organs of birds, but because the bacteriologic identification of the disease has been attempted by these workers while it has been quite neglected by ourselves. If, however, the identification of the nature of this infection is established in the case of the fowl, there can be little doubt that at least nearly all the data presented here are likewise from true cases of avian tuberculosis. We had learned to recognize tuberculosis in the fowl prior to our more extensive experience with pigeons; the similarities of the disease in the two forms are too pronounced to be easily mistaken.

One statement concerning the external symptoms of the disease as it presents itself in the pigeon may be added: Emaciation is not evident; assuredly it is not prominent in all cases of advanced tuberculosis; and we have listed as unquestionable some cases of tuberculosis in ring-doves with abnormally high body weight and in which the large pectoral muscles were of normal or nearly normal size. In these cases the excess weight was largely accounted for by the enlargement of the

liver and spleen; in some instances the latter organ was enlarged from 0.1 gm. to 11.0 gm. On the other hand, it is our opinion that advanced tuberculosis in the pigeon is always accompanied by resorption in the ovary of all ova of more than 1.0 mm. diameter, and by extreme atrophy of the testes.⁸ Rarely does death from another cause bring about so profound a change in these organs.

Our data were obtained from 940 tuberculous *Columbidæ* which we have divided according to kind or origin into 5 groups. Nearly three fourths of these birds were adults dead of disease; about 215 (mostly belonging to group 3) were older than 3 months and were either killed for necropsy while supposedly healthy or were killed by accident. The method used in obtaining these data do not permit a numerical statement of the proportion of all doves which are attacked or killed by tuberculosis; this proportion, however, is high among those individuals, in most or all kinds of pigeons, which are otherwise permitted to live their full span of life. The intestines of many of the tuberculous birds were found to be also badly infested with *Ascaridia*. Other diseases were of course also occasionally present and in some instances these were accompanied by tuberculosis. The head and neck regions were not included in the necropsies except as these plainly displayed bone or joint tuberculosis. The lymphatic glands, thyroid, crop, etc., are omitted in our necropsies and tabulations.

Table 1 gives the details of data obtained for the 5 groups. The data indicate that in pigeons the spleen and liver are each about twice as often the seat of tubercle formation as are the lungs, and that the latter are about 3 times as often infected as the mesenteries; the joints, ovaries, abdominal wall and intestine follow next in order; in still other organs the tubercles are rarely but probably not equally rarely found. In all groups except the common pigeons the spleen is shown to be the most frequently infected organ. The liver ranks second in 4 cases and first in the group of common pigeons. The lungs rank third in 4 cases and fourth in 1. It is again among the common pigeons that this irregularity appears—the joints here being more often infected than the lungs. Elsewhere the joints rank fourth in two groups and fifth and seventh in the other 2 groups. The mesenteries were more often infected than the joints in only 2 of the 5 groups, but the sum of all groups shows a considerable excess of infected mesenteries. The ovary ranks sixth, the intestine seventh and the abdominal wall eighth. Other organs are infected with incon-

⁸ Riddle, O.: *Anat. Rec.*, 1918, 14, p. 283.

siderable frequency. Our data indicate—though the numbers of recognizable infections are here so few as to be of rather uncertain value—that these organs take the following order: testes, kidney, oviduct, pericardium, suprarenals, pancreas, heart, gizzard and cloaca.

The details of the tabulated data—omitted here to economize space—make it clear that in all groups of birds the particular organ which was most often infected was at the same time the most affected organ in the greatest number of cases. Perhaps this circumstance may be taken as an indication that the most frequently infected organs are themselves the seats of the primary infection.

The numbers are large enough and the agreement of the 5 groups is close enough to make it quite clear that the spleen, liver and lungs are most extensively, as well as most often, infected; and that these organs are infected in essentially the order named, with the exception that in common pigeons the liver is probably more frequently the seat of attack than is the spleen. It is highly probable that the mesenteries, joints and intestines follow, but not necessarily in this order, in all groups of pigeons. For the other organs it is certain only that the number of infections is small and markedly less than in any of the organs mentioned in the foregoing in the kinds of pigeons which we have examined. In the case of some of these infrequently infected organs, such as the suprarenal and testis, it is quite possible that the infection originated external to them and merely enclosed or surrounded them.

It is of interest that the data afford good evidence that the ovary is more often the seat of infection than is the testis. The present data were collected incidental to investigations on sex; the gonads were therefore examined with particular care in the necropsy examination of every bird—not only of the 940 individuals showing tuberculosis, but in many thousands of healthy pigeons whose ages ranged from embryos to adults. Other cases than those listed of advanced tuberculosis in these organs were almost certainly not present. Very few, however, of the cases of tuberculous gonads listed were examined microscopically (none were stained for bacilli) and it is possible that some or several of the cases listed were really tumors, not tuberculous. Proper classification of disease in these organs by macroscopic observation is made questionable and especially difficult by the circumstance that the size of the testes is greatly diminished, often to one-fiftieth of their full and functional size, in the case of males whose other organs showed advanced tuberculosis.³ In the ovary there is little or no corre-

sponding change of size when the spleen, liver, lungs, etc., are highly tuberculous; but, in these ovaries all ova of more than 1.0 mm. atrophy and no younger ova advance beyond this size.

It is notable that among the common pigeons the testis is as often infected as is the ovary. Indeed, tuberculous testes were almost wholly absent in other groups. Five of the total of 7 cases of tuberculous testis were supplied by only 57 tuberculous male common pigeons while the 317 male ring-doves of group 3 yielded no cases of tuberculous testis; the 306 females of the latter group supply 14 cases of such ovaries. Here once more the differences in the incidence of tuberculosis in common pigeons and in other pigeons is marked. The rank or order of infection assigned in the tables to the sexual organs takes account of the fact that the numbers of males and females in the 5 groups were: group 1, 57 males and 63 females; group 2, 35 males and 22 females; group 3, 317 males and 306 females; group 4, 38 males and 27 females; group 5, 39 males and 18 females; a total of 486 males and 436 females. The few remaining birds were either hermaphroditic or for some other reason their sex could not be ascertained. A total of 18 of the 940 birds are unclassified as to sex and of this number 17 are from the 2 groups of generic hybrids.

DISCUSSION

It has been observed that the spleens and livers include more than two thirds of the instances of tubercle-bearing organs.

Kyes⁴ found that the endothelial cells (hemophages, Kupffer cells) of precisely these two organs in the pigeon remove nearly all intravenously injected pneumococci from the blood stream. Kyes says, p. 282:

"At all intervals between 10 minutes and 72 hours the liver contained many more pneumococci than did any other organ. The spleen ranked next. . . . Cell for cell, the hemophages of the spleens contained as many pneumococci as did those of the livers. The absolute numbers of hemophages was, however, as in normal pigeons, distinctly smaller."

Here also the lungs were found to rank third in order of importance and in "other organs the numbers were relatively inconsiderable"—microscopic examination failing entirely to find the organisms in breast muscle and genitalia.

In other animals some interesting parallels and contrasts are known. In rabbits Hopkins and Parker⁵ found 10 minutes after intravenous injection of streptococci the following distribution of the organisms: spleen, 120,000; liver, 104,000; lung, 41,000; psoas, 1,500; kidney, none. These figures for this property of the organs of the rabbit may be seen by reference to our summary table to afford an odd and nearly perfect parallel—even on a percentage basis—of the foregoing to the relative incidence of tuberculosis in the organs of most

⁴ Jour. Infect. Dis., 1916, 18, p. 277.

⁵ Jour. Exper. Med., 1918, 27, p. 1.

kinds of doves other than common pigeons. In cats, however, Hopkins and Parker found quite a reverse order of distribution of the organisms in the three organs chiefly involved, namely: spleen, 18,000; liver, 34,000; lungs, 315,000.

In their recent study of the distribution in the cat of finely divided manganese dioxide after intravenous injection, Drinker and Shaw⁶ were able, when a particular concentration was used, to recover 90% of this material in the lungs, liver and spleen, and in the following proportions: lungs, 47%; liver, 38.4%; spleen, 4.3%. It is thus clear that the order of distribution of the manganese dioxide is similar to the distribution of the streptococci found by Hopkins and Parker for the organs of the same animal. Drinker and Shaw state, p. 91:

"Although we cannot make a direct and final comparison between the intravenous bacterial injections and intravenous injections of nonliving material such as the manganese dioxide used in this study, it seems established that in as far as the immediate removal from the blood stream is concerned the two types of injection are treated similarly by the animal."

The studies last mentioned are cited because of the nature of the analogy involved and even more because in a further publication by Lund, Shaw and Drinker⁷ this study has been extended to other animals, including one bird—the common fowl. In this bird the manganese dioxide was recovered as follows: from the liver, 84.0%; spleen, 1.7%; lungs, 0.2%; all other organs, 14.1%. From these and other figures tabulated by these workers it is fairly clear that this nonliving substance is distributed in the organs of the fowl in nearly the same relative order as those of the rabbit and quite differently from the order found for the cat. And, as noted in the foregoing, both the relative order and percentage distribution of the streptococci in the rabbit is closely parallel to the frequency of tuberculous infection in fowls and pigeons. The relative order of distribution of the manganese in the organs of the fowl is also rather similar to the incidence of tuberculous infection in the pigeon, although the percentages involved are apparently quite different.

The correspondence to which attention has just been drawn may afford a slight basis for the suggestion that the various organs of the pigeon become the seat of tuberculous infection with a frequency which is proportional to the number of infecting organisms which they remove from the blood stream. Stating the point otherwise, we may say that earlier work has demonstrated the phagocytic capacities of the various organs of the pigeon to be of about the same relative order as we now find these organs infected with tuberculosis.

It remains to mention two further incidental points of possible interest. The data may be of slight value in a consideration of the question whether tropical species brought to or reared in New York are more or less susceptible to pulmonary tuberculous infection than are species native to temperate climates. The results fail to indicate any such influence. It should be stated, however, that all of these birds

⁶ Jour. Exper. Med., 1921, 33, p. 77.

⁷ Jour. Exper. Med., 1921, 33, p. 231.

were protected from extreme cold in heated buildings. It is obvious, moreover, that the birds which supply the present data may have been affected or predisposed, or certain organs thrown under special strain, by the general nutritive or other conditions provided by us and that this may have affected the data obtained for all of the groups. Concerning this it can be said that, because of the nature of the work being

TABLE 1
CONDENSED SUMMARY ON THE INCIDENCE OF TUBERCULOSIS IN PARTICULAR ORGANS IN THE
PIGEON. NUMBER OF PLAIN CASES OF TUBERCULOSIS (= A) AND OF PROBABLE
EARLY STAGES (= B) *

	Group I 120 Birds		Group II 57 Birds		Group III 624 Birds		Group IV 76 Birds		Group V 63 Birds		Total 940 Birds	
	A	B	A	B	A	B	A	B	A	B	A	B
Spleen.....	36	4	34	2	465	80	54	11	29	7	618	104
Liver.....	51	23	27	12	394	102	38	20	27	12	537	119
Lungs—Both....	9	0	17	0	75	15	9	1	12	0	122	16
Right.....	10	0	5	0	73	1	10	0	10	0	108	1
Left.....	12	0	5	0	40	0	0	0	5	0	63	0
Total.....	31	0	27	0	188	21†	25	1	27	0	298	22
Mesentery.....	27	0	1	0	64	3	10	0	4	0	106	3
Joints.....	38	0	6	1	18	1	5	0	7	0	74	2
Intestines.....	6	0	3	0	29	6	4	1	...	...	42	7
Abdominal wall..	12	1	4	0	21	0	5	0	3	0	45	1
Gonads†—Ovary	6	2	1	0	14	9	3	1	1	0	25	12
Testis.....	5	3	1	1	0	1	1	0	...	...	7	5
Kidney.....	2	0	2	0	3	2	2	0	2	0	11	2
Oviduct.....	1	0	...	...	2	1	...	...	1	1	4	2
Pericardium.....	2	0	1	0	...	...	2	0	1	0	6	0
Suprarenals.....	1	1	1	0	0	4	...	...	...	...	2	5
Pancreas.....	2	0	...	...	1	1	...	...	...	...	3	1
Heart.....	...	...	...	...	2	0	0	1	1	0	3	1
Gizzard.....	...	...	1	0	2	0	...	...	...	...	3	0
Cloaca.....	...	...	...	...	...	...	1	0	1	0	2	0
Indefinite record.	7	...	...	...	4	1	...	...	2	...	14	...
Totals.....	227	34	109	16	1,207	232	150	35	106	20	1,799	337

* Group I composed of common pigeons and a few individuals of wild species of genus *Columba*.

Group II composed of pure species, mostly tropical genera (*Turtur*, *Spilopelia*, *Stigmatopelia*, *Ocyphaps*, *Phaps*, *Geopelia*).

Group III composed of *Streptopelia risoria*, *St. alba*, *St. douraca*, and their hybrids.

Group IV composed of generic hybrids of *Turtur orientalis* and *Streptopelia alba* and *risoria*.

Group V composed of generic hybrids of *Stigmatopelia*, *Zenaida*, *Zenaidura*, *Spilopelia* and *Streptopelia*.

† Five cases of "lung suspected" but right or left not designated.

‡ The ovary really ranks sixth (i. e., before "intestines" and "abdominal wall") because the numbers given are based on one sex only. The oviduct takes the place indicated for the same reason.

done with these birds, they were given the best of care during nearly all of this period. This care included: fairly ample, essentially clean and light quarters; abundant and presumably suitable food; the opportunity to mate at maturity (though many were not permitted to rear young); freedom from vermin or body lice in most cases; and protection from extreme cold in heated buildings during the winter.

The data offer some evidence on the question whether the organs of distinct hybrids—crosses involving different genera—are differently susceptible to this particular infection in comparison with the organs of the parent species. There is a high degree of similarity of all these groups. The spleen, liver and lungs take this order in the four groups. The evidence obtained indicates that in pigeons the chief sites of tuberculous infection, or at any rate the infections uniformly considered by us to be tuberculous, are not changed by the fact that these organs are the product of an extremely wide hybridization.

SUMMARY

Statistical data are given for the relative extent to which the various organs of 940 Columbidae were infected with tuberculosis or with a macroscopically similar infection. Bacteriologic examinations of these infections were not made, but there can be little doubt that most of these were cases of infection by avian tuberculosis bacilli.

Four of the five groups examined show the spleen, liver and lungs infected in this relative order; the spleen and liver alone include about two thirds of the total number of the obviously infected organs of the body.

The common pigeons present a similar yet appreciably different ranking of infected organs since the relative order for this group probably is: liver, spleen, joints and lungs.

The organs most often infected are apparently also the most intensively or extensively infected organs.

It is suggested that since the order of infection of organs in common pigeons is essentially the same as the order in which the organs of these birds remove intravenously injected bacteria, as shown by Kyes, there is some sort of causal connection between the two facts.

Results recently obtained by other investigators on the distribution of injected manganese dioxide in the fowl also seem to invite the suggestion that the organs which probably remove most of such finely divided nonliving particles and most infecting bacteria from the blood stream are the organs most often infected by tuberculosis.

The ovary is probably more often infected than is the testis in most groups of pigeons; in domestic or common pigeons the data indicate an equal susceptibility of ovary and testis to this infection.

The organs of hybrid birds derived from different genera are probably not changed in their relative susceptibility to tuberculous infection by the mere fact that these organs are of hybrid origin.